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INTER-RELATIONSHIPS BETWEEN SOIL-PROTECTING LAND USE SYSTEMS, RECREATION AND TOURISM ON AGRICULTURAL LANDSCAPES IN LITHUANIA

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Abstract

Soil degradation by soil erosion is evident on the hilly-undulating landscape, when common land use systems, containing tillage crops, are practised by land owners. Results of long-term field investigations enable the proposal of specific erosion-resistant land management systems, which enable us to localize and stabilize erosion processes on areas most vulnerable to soil erosion. It is feasible to implement soil-protecting land use systems (i.e. erosion-resistant crop rotations and long-term perennial grasses) designed for fields of varying size, slope gradient and soil texture. These agro-environmental aims can be integrated with rural tourism, thus enabling rehabilitation of degraded land and improving the socio-economic situation of rural villages. Matching specific soil tillage operations with intensity of fertilization permits further retardation of soil erosion intensity. The proposed vision of the modern Lithuanian village is thus to recommend new activities for local land owners and to promote sustainable and environmentally-friendly economic development.

Keywords: *eutric Albeluvisols, hilly-undulating landscape, soil erosion, socio-economic situation, economic development*.

Introduction

Research problem and relevance. Soil is one of the most important natural resources influencing community development. Some soil properties are vulnerable to degradation on the hilly undulating landscape. Soil erosion processes deplete topsoil, decrease soil organic matter (SOM) content, deteriorate soil physico-chemical properties and level landscape topography. Therefore, sustainable community development on the hilly undulating landscape must meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability depends on different circumstances and conditions. One land use system can meet the needs of the present community, but lead to future land degradation. Solving these problems is of paramount importance.

The main form of soil erosion on arable land in Lithuania is tillage erosion. Water and wind erosion occurs on arable slopes and wind erosion occurs on the Baltic Sea coast and large areas of peaty-sandy arable soils (Jankauskas, Jankauskiene, 2003a). Some 51.9% of Lithuania's terrain has a hilly-undulating relief, where soil is vulnerable to erosion processes.

Theoretical background of investigations. Soil erosion is one of the world's most serious environmental problems, causing extensive losses of cultivated and potentially productive soil and an enormous annual loss of crop yields (Fullen, Catt, 2004; Morgan, 2006). Highly eroded soils tend to have reduced productivity, degraded soil structure, lower SOM and a poor environment for root growth (Morgan, 2006). Soil erosion on the hilly undulating agricultural landscape is a complex phenomenon involving the detachment and transport of soil particles, storage and runoff of rainwater and infiltration. The relative magnitude and importance of these processes depends on many factors, including climate, soil, topography, cropping and land management practises, antecedent conditions and scale (Römkens et al., 2002). Complexity of soil erosion phenomena determines different soil erosion processes, such as tillage erosion, water erosion and wind erosion. The removal of soil by one erosion process can affect the erodibility of the remaining soil to other erosion processes, and one soil erosion process can act as a delivery mechanism for other erosion processes, by depositing soil where it is more readily removed by other erosion processes. Soil erosion also impacts other processes, such as water contamination with sediments and nutrients, pesticide fate in the soil and the environment, and greenhouse gas production and emission. These interactions complicate modelling efforts and there are tremendous opportunities to increase the accuracy, coherency and efficiency of environmental indicator initiatives (Lobb et al., 2003). However, many techniques can be used to conserve soils, each with their own relative advantages and disadvantages. Any successful soil conservation plan is a mix of technical and social objectives. Developing effective and viable soil conservation strategies is one of the most pressing soil management problems we face in the early twenty-first century. These strategies must be both cost-effective and socially acceptable (Fullen, Catt, 2004).

The cover crops composing agro-ecosystems play key roles in promoting biodiversity (Vandermeer et al., 1998), therefore, multi-species agro-ecosystems (sod-forming long term perennial grasses and grass-grain crop rotations) are potential components for both soil conservation and biodiversity strategies. Furthermore, the global dataset of soil erodibility values shows much unexplained variance and a contributory factor is often the limited measurement period (Torri et al., 1997). Therefore, long term studies are essential to both assess changes in soil physical properties and the potential of soil conservation techniques (Chan et al., 2002).

Soil erosion processes are partially responsible for CO_2 concentrations in the atmosphere leading to increased 'greenhouse effects'. Global CO_2 concentrations are increasing; therefore it is useful to study these changes in terms of carbon 'sources,' 'sinks' and 'pools' (Batjes, 1996, Lal, 2002; 2003). Considerable amounts of organic carbon can be sequestered into soils, as carbon is an integral part of SOM. Soil organic carbon (SOC) constitutes ~58% of SOM (USDA, 1996). The potential to sequester atmospheric carbon within the soil store is a growing paradigm in soil science. The consensus is that C-sequestration is not a panacea to global warming, but sequestration and storage would form a valuable contribution and allow extra time while solutions to the problems are sought (Fullen, Catt, 2004).

The extent and severity of erosion on European soils has markedly increased over the last 50 years, particularly on arable land. Unfortunately, soil conservation in Europe generally has not received sufficient attention, until recently (Boardman, Poesen, 2006; Fullen et al., 2006). Set-aside is a scheme designed to provide farmers with a subsidy to leave land uncultivated and can thus act as a soil conservation measure (Chisci, 1994; Fullen, 1998). In the prevailing economic climate, it is feasible that steep to moderate slopes with erodible soils, and other vulnerable parts of fields (i.e. depressions, minor dry valleys and land adjacent to water courses), be put into non-rotational set-aside (Environment Agency, 2001; MAFF, 1998). This could decrease erosion rates and potentially increase SOM content, with concomitant decreases in soil erodibility.

In the UK in 1995, the Moorland Scheme (MS) was launched with the objective of protecting and improving the upland moorland environment. In 1998, the Arable Stewardship Pilot Scheme (ASPS) was created to assess alternative arable management options for conserving and enhancing farmland biodiversity (Ecoscope, 2003).

In Lithuania, erosion-resisting recommendations for land users were prepared on the basis of investigations at Kaltinėnai Research Station of the Lithuanian Institute of Agriculture. The results of investigations were discussed at scientific conferences and workshops, and were propagated and disseminated by scientific (Jankauskas, Jankauskienė, 2004) and popular (Jankauskienė, Jankauskas, 2005; Jankauskas, Jankauskienė, 2006) publications. Results of investigations from the first and second crop rotations (1983-1994) have been reported by Jankauskas and Jankauskienė (2000; 2003a) and from the third crop rotation (1983–2000) by Jankauskas (2003); Jankauskas, Jankauskienė (2003b,c) and Jankauskas et al. (2004).

Goals and objectives. The main goal of investigations was to design optimum land use systems meeting the needs of the present community, and which could be evaluated as friendly for future generations. The main objectives of our investigations were:

- To prepare simple strategies for the stabilization of soil erosion and for improving ecological conditions on the vulnerable hilly-undulating landscapes.
- To evaluate the potential for soil conservation on eroded undulating land.
- To advise land users and policy makers on rural development in relation to environmental protection.
- To distribute results of investigations for possible implementation in other temperate climatic zones, thus promoting international co-operation in the development of erosion-resistant agro-environmental systems.

Research methods

Research data were obtained from the Kaltinenai Research Station of the Lithuanian Institute of Agriculture (KRS of LIA). Dystric Albeluvisols (ABd) (*nepasotintieji balkšvažemiai*) prevail in this region of Lithuania. However, soils become Eutric Albeluvisols (ABe) (*pasotintieji balkšvažemiai*) due to intensive periodical liming, when lime changes the properties of both Ap and deeper soil horizons. Study sites A, B and C are on slopes of 2–5, 5–10 and 10–14°, respectively.

Field experiments were used to evaluate ecological and agrarian situations. Field experiments were performed on eroded Eutric Albeluvisol sandy loams (IUSS, 2006). Soil was differentially eroded along the slopes, being slightly eroded on 2–5° slopes, moderately eroded on 5–10° slopes and strongly eroded on 10–14° slopes, with colluvial deposits on basal slopes. Soil erosion was mainly caused by tillage and water erosion under continuous intensive cropping. The agro-chemical properties of Ap horizons (0–20 cm) before field experiments shows topsoils were slightly acid, P-deficient, medium rich in K and contained varying SOM contents (Table 1). The highest percentage SOM was on less eroded 2–5° slopes and the least on 10–14° slopes. For historical reasons, soil analytical techniques were mainly former Soviet procedures (Jankauskas and Fullen, 2002). Therefore analytical results differ from those generated by currently internationally-accepted protocols (e.g. USDA, 1995), but are consistent with former Soviet protocols (Jankauskas and Jankauskiene, 2003a). Pre-transfer functions to convert data between Soviet and international systems were proposed by Booth et al. (2003) and Jankauskas et al. (2006).

Table 1

Mean soil chemical properties of the arable (Ap) horizon (0-20 cm) before field experiments in 1981

Study sites	Slope steepness (degrees)	pH_{KCl}	Available elements (mg kg^{-1})		Exchangeable bases (cmol(+)kg^{-1})	Organic matter (g kg^{-1})
			P	K		
A	2–5	5.8	49.8	146.1	119	28.5
B	5–10	5.3	18.3	127.0	94	22.0
C	10–14	5.8	29.7	131.2	96	20.8

Mean annual precipitation in Lithuania is 626 mm, with ~858 mm on the central Žemaičiai Uplands and 750–800 mm on the upland fringe. Annual precipitation during the study period was 635–1075 mm. Plots were deep-ploughed (where needed), usually in September, and were bare until spring. Total runoff and erosion from bare soil was measured before the following spring cultivation (usually in mid-April). Plot runoff and erosion were measured on a regular basis, up to weekly during erosive rains, after sowing. Measurements were taken from spring sowing (typically late April or early May) to mid-June for cereals and late August for potatoes. Long-term field experimental data were collected on slopes of 2–5, 5–10 and 10–14° since 1983. Four crop rotations were compared (Fig. 1), specifically:

a) The field crop rotation, containing 17% tillage crops (potato), 33% grasses and 50% cereal grains: 1: winter rye (*Secale cereale* L.), 2: potatoes (*Solanum tuberosum* L.), 3–4: spring barley (*Hordeum vulgare* L.), 5–6: mixture of clover-timothy (CT) (*Trifolium pratense* L.-*Phelum pratense* L.).

b) The grain-grass crop rotation, containing 33% grasses and 67% cereal grains: 1: winter rye, 2–4: spring barley, 5–6: CT.

c) The grass-grain I crop rotation, containing 67% grasses and 33% cereal grains: 1: winter rye, 2: spring barley, 3–6: CT.

d) The grass-grain II crop rotation, containing 67% grasses and 33% cereal grains: 1: winter rye, 2: spring barley, 3–6: mixture of orchard grass-red fescue (OF) (*Dactylis glomerata* L.-*Festuca rubra* L.).

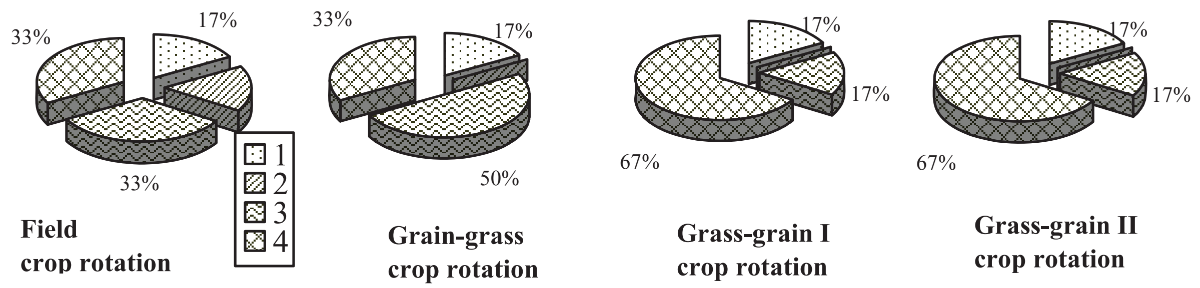

Fig. 1. Structure of investigated crop rotations (%): 1. Winter rye, 2. Potatoes, 3. Spring barley, 4. Perennial grass mixtures (clover-timothy (I) or orchard grass-fescue red (II)).

Multi-species mixtures of perennial grasses for long-term use as sod-forming grasses g) were grown on 10–14° slopes instead of the field crop rotation. The grass mixture consisted of 20% each of common timothy, red fescue, white clover (*Trifolium repens* L.), Kentucky bluegrass (*Poa pratensis* L.) and birdsfoot trefoil (*Lotus corniculatus* L.). Grass ley replaced the field crop rotation, as tilled crops are not recommended in Lithuania on slopes >10° (Jankauskas, 1996).

The statistical analysis of research data was used for evaluation of the significance of differences among the data sets and were determined using Fisher's LSD_{05} using computer programs ANOVA and STAT from the package SELKCIJA and IRRISTAT (Tarakanovas, Raudonius, 2003).

The methods of modelling, logical abstraction and contrastive analysis were used for the formulation of land use systems on the basis of experimental data and statistical analysis.

Results and discussion

Rates of water erosion. Arable soils are eroded by tillage operations, water, and wind on the hilly-rolling relief. The natural fertility of the soil on the slightly, moderately and severely eroded slopes of the Žemaičiai Uplands has decreased by 21.7, 39.7 and 62.4%, respectively, compared with soil fertility on non-eroded soil (Jankauskas, Jankauskiene, 2004). This was due to soil degradation under the influence of erosion processes: bulk density and the percentage of clay-silt and clay fractions increased, while the total porosity and water field capacity decreased on eroded topsoil. The strong acidity of the E, EB and B1t horizons, and the increased acidity throughout the soil profile are characteristic features of Dystric Albeluvisols (Jankauskas, 1996; Jankauskas et al., 2007).

Measured water erosion rates on arable slopes were: 3.17-8.6 m^3 ha^{-1} yr^{-1} under winter rye, 9.01–27.09 m^3 ha^{-1} yr^{-1} under spring barley and 24.2–87.12 m^3 ha^{-1} yr^{-1} under potatoes, according to results of 18 years of field experiments. Perennial grasses completely prevented water erosion. The mean water erosion rates under the field crop rotation varied from 6.43–20.5 m^3 ha^{-1} yr^{-1} on slopes of 2–5, 5–10 and 10–14°. The erosion-preventive grass-grain crop rotations (>50% grass) decreased soil losses on arable slopes of 2–5, 5–10 and 10–14° by 74.7–79.5%, respectively, while the grain-grass crop rotation (<50% grass) decreased rates by 22.7–24.2% compared with the field crop rotation (Jankauskas et al., 2004). Water erosion rates increased with increasing slope. They were 9.9, 23.4 and 32.2 Mg ha^{-1} yr^{-1} on slopes of 2–5, 5–10 and 10-14°, respectively, under the field crop rotation; 7.5, 18.0 and 24.9 Mg ha^{-1} yr^{-1} under the grain-grass crop rotation and 2.5, 4.8 and 7.3 Mg ha^{-1} yr^{-1} under the grass-grain crop rotation. Water erosion rates varied in response to soil texture: the least soil losses (0.45–3.59 Mg ha^{-1} y^{-1}) were from the slope with the heaviest soil texture (silty clay loam). Somewhat higher soil losses (0.65–6.29 Mg ha^{-1} y^{-1}) were from the slope with silt loam and the highest water erosion rates (4.38–29.38 Mg ha^{-1} y^{-1}) were from the slope with the lightest soil texture (silt loam) (Jankauskas and Jankauskiene, 2003b).

Changes in soil organic matter content. Evaluation of the role of SOM in soil degradation by erosion and the formulation of strategies for soil C-sequestration are important components of soil protection strategies. SOM accumulation is a slow process and considerably slower than the decline (Lal et al., 1998). Fortunately, accumulation can be enhanced by positive farm management techniques, such as permanent grassland, cover crops, conservation tillage (including no-tillage cropping techniques), mulching, green manures and applications of farmyard manure and compost. Most of these techniques have also proved effective in preventing erosion, increasing fertility and enhancing soil biodiversity (Lal, 2002). Therefore, determining the dynamics of SOM content is possible only by adopting long-term investigations (field experiments and periodical soil analysis).

The results of SOM content changes in long-term field experiments at the KRS illustrate multiple influences of land use systems on SOM dynamics (Table 2). Firstly, the variety of crops as constituents of the rotation can differentially affect C-sequestration processes (Jankauskas, 1996; Lal et al., 1998). Secondly, different land use systems require different intensities of soil tillage. Consequently, more intense soil tillage stimulates more SOM mineralization, which releases more C from the soil store to the atmosphere (Lal, 1999). Thirdly, there were different soil losses due to water erosion under different land use systems: highest losses were under the field crop rotation and the least were under grass-grain crop rotations (Jankauskas and Jankauskiene, 2003a; Jankauskas et al., 2004). The higher soil losses lead to higher losses of SOM. Furthermore, different land uses influence C-sequestration by changing soil physical properties, such as dry bulk density, total soil porosity and moisture field capacity. At KRS, the erosion-preventive grass-grain crop rotations and long-term perennial grasses significantly increased total porosity and moisture field capacity (Jankauskas et al., 2008).

There were small changes in % SOM after both the first and even the second crop rotation (Table 2). However, differences in % SOM become more evident after the third crop rotation in 2000. Significantly higher SOM values were found under the grass-grain crop rotations on the 2–5° and 5–10° slopes compared with the field crop rotation, and under the sod-forming perennial grasses on the 10–14° slope compared with the grain-grass crop rotation. The results demonstrate that sod-forming perennial grasses on 10–14° slopes and grass-grain crop rotations on 2–10° slopes enable land rehabilitation.

Table 2

Mean SOM contents under different land use systems

Time of analysis	SOM (%) after the crop rotations (c.r.):				LSD_{05}
	field c.r.	grain-grass c.r.	grass-grain I c.r.	grass-grain II c.r.	
2–5° slope					
1988, after 1st c.r.	3.47a*	3.46a	3.08a	3.23a	0.412
1994, after 2nd c.r.	2.73a,b	2.54a	3.65b	3.47b	0.301
2000, after 3rd c.r.	2.64a	2.99b	3.39c	3.46c	0.284
5–10° slope					
1988, after 1st c.r.	2.52a	2.47a	2.48a	2.41a	0.287
1994, after 2nd c.r.	2.37a	2.35a	2.27a	2.31a	0.169
2000, after 3rd c.r.	2.17a	2.01a	2.75 b	2.67b	0.1.64
10–14° slope					
1988, after 1st c.r.	2.49a**	2.42a	2.71b	2.50a	0.232
1994, after 2nd c.r.	2.59b**	2.24a	2.47b	2.39a	0.221
2000, after 3rd c.r.	2.51b**	1.99a	2.45b	2.43b	0.328

*Values with the same letter subscript are not significantly (LSD_{05}) different comparing values among treatments; g)** The sod-forming perennial grasses were grown instead of the field crop rotation on the 10–14° slope; n = 4 soil samples, with each sample consisting of a mixture of 30 individual samples.

Comparable results were found at the Hilton Experimental Site, Shropshire, UK. Conversion of 10 erosion plots from bare arable to grass ley set-aside reversed the trend of declining SOM contents, which then significantly increased, especially in the first four years. Mean SOM content (0-5 cm depth) significantly (LSD_{001}) increased from 2.04% by weight (SD 0.45, n = 50 samples) in April 1991 to 3.11% (SD 0.68, n = 50 samples) in April 2001, compared with permanent grassland values of ~4.5%. Soil erodibility after six years of set-aside (sampling date 24/04/97) was determined using a drip-screen rainfall simulator. Soil aggregate stability was higher on the grassed soils, compared with set-aside and bare arable soils. Despite no significant (LSD_{05}) differences between grassland and set-aside soils, both these treatments were significantly (LSD_{001}) greater than bare soils (Foster et al., 2000).

Generally, higher soil losses promote greater SOM loss. Furthermore, various land use systems influence erosion rates and changes in soil physical properties. Erosion-preventive grass-grain crop rotations and perennial grasses for long-term use significantly increased SOM on 2–5° and 5–10° slopes, compared to field crop rotations. Sod-forming perennial grasses significantly increased SOM on 10–14° slopes compared with the grain-grass crop rotation (Fig. 2).

Developing terrain erodibility groups. Analysing the complex hilly-rolling relief of the Lithuanian Uplands, water erosion on arable slopes varied with slope inclination and soil texture. The most vulnerable to the water erosion were terrains having light soil texture on steep slopes. However, cover crops determined water erosion rates on the different soil and landscape conditions. Therefore, the main attributes of the proposed land conservation and sustainable land-use system were the careful selection of optimum erosion-preventive agri-phytocenoses (sod-forming perennial grasses or erosion-preventive crop rotations) with high erosion-resisting capabilities. These systems vary in response to slope and soil conditions. Such agro-ecosystems assist erosion control and thus the ecological stability of the undulating topography, being the main component for soil protection strategies on the undulating land within a temperate climate zone.

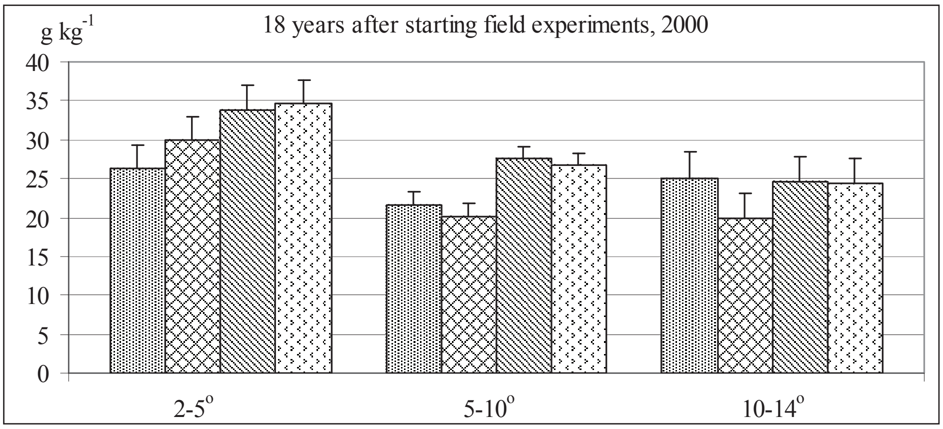

Fig. 2. SOM contents (g kg^{-1}) under different land use systems 18 years after commencing field experiments
Legend – columns: 1) field crop rotation (the sod-forming perennial grasses were grown instead of the field crop rotation on the 10–14° slope); 2) grain-grass crop rotation; 3) grain-grass I crop rotation; 4) grass-grain II crop rotation. Slope steepness: 2–5, 5–10 and 10–14°.

The erosion prevention grouping of erodible hilly-undulating terrain contains five landscape groups, depending on slope gradient and soil texture (Table 3). The requirements for identifying groups and recommended soil conservation measures were formed using research data from field experiments. Group I includes highly erodible soils on slopes <10^0, having sandy, loamy sand or gravel textures (light soils) or on slopes <15^0 with loamy or clay textures (heavy soils). We suggest planting trees on such slopes increasing woodland and biodiversity and enabling C-sequestration and storage to decrease greenhouse effects.

Table 3

Grouping erodible terrain for improved soil conservation

Groups	Soil texture†		Type of land use	Requirements for group formation	Recommended erosion-resisting measures
	S, LS, G	L, C			
I	<10^o	<15^o	Wood-land	To identify slopes >$10–15^o$. Slopes >10^o with heavy texture and >5^o with light texture are unsuitable for land reclamation.	To plant trees or shrubs, to carefully maintain perennial grasses.
II	$7–10^o$	$10–15^o$	Grass-land	Along with the indicated slopes to annex the inconvenient for tillage, more plain arable plots and to establish pasture or grassland.	To plant perennial grasses for long-term use. To renovate grasses by introducing more varied compositions. Cover crop must be annual grasses.
III	$5-–7^o$	$7–10^o$	Arable land or grass-land	Similar to Group II, only indicated plots must be suitable for tillage.	To put into practise the erosion-preventive grass-grain crop rotation. To apply erosion-preventive tillage.
IV	$2–5^o$	$3–7^o$	Arable land	Similar to Group III, only 10% of light soil slopes ≤7^o can be annexed.	To put into practise the erosion-preventive grain-grass crop rotation. To apply erosion-preventive tillage. To avoid growing of tillage crops and flax.
V	≤2^o	≤3^o	Arable land	Plains, suitable for tillage practise, these remained after forming Groups I–V.	To use intensive field crop rotations. On $2–3^o$ slopes to apply soil conserving tillage practises.

† S: Sand, LS: loamy sand, G: gravel, L: loam, C: clay.

Long-term perennial grasses. Growing long-term perennial grasses is recommended (Table 4) on light soils with prevailing $7–10^0$ slopes and heavy soils with $10–15^o$ slopes, and on surrounding soil that is unsuitable for any other exploitation (Group II). Because perennial grasses provide full protection from soil erosion, even on $10–15^o$ slopes, the grass mixtures with a high percentage (90%) of common alfalfa *(Medicago sativa* L.) are recommended for hilly pastures, if soils were suitable for growing alfalfa. The annual average yield was 6.12 Mg ha^{-1} dry matter or 0.92 Mg ha^{-1} digestible protein. However, most soils on the Žemaičiai Uplands are unsuitable for growing alfalfa, due to excess soil acidity and extensive waterlogged subsoil. Therefore, grass mixtures of high fertility for early, medium and late hay-making or grazing were established. The annual average productivity of the most fertile hay meadow mixture during a 6-year period was 7.9–9.2 Mg ha^{-1} dry matter. The productivity of the pastureland was 5.6–7.1 Mg ha^{-1}. The productivity of these grass mixtures did not decrease during a 6-year period, indicating that the duration of these grass mixtures might be longer (Norgailienė and Zableckienė, 1994). These long-term perennial grass mixtures can be used for grasslands on areas in Group II with erodible terrain.

Table 4

The erosion-resistant crop rotations for Group III fields (see Table 3)

I . ≤80% grasses 1. Winter grains or spring barley, 2. Perennial grasses, 3. Perennial grasses, 4. Perennial grasses, 5. Perennial grasses.	II. ≤74% grasses 1. Winter grains, 2. Spring barley, 3. Perennial grasses, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses, 7. Perennial grasses.	III. ≤67% grasses 1. Winter grains, 2. Spring barley, 3. Perennial grasses, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses.
IV. ≤63% grasses 1. Winter grains, 2. Winter grains, 3. Spring barley, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses, 7. Perennial grasses, 8. Perennial grasses.	V. ≤63% grasses 1. Winter grains, 2. Spring barley, 3. Spring barley, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses, 7. Perennial grasses, 8. Perennial grasses.	VI. ≤60% grasses 1. Winter grains, 2. Spring barley, 3. Perennial grasses, 4. Perennial grasses, 5. Perennial grasses.

Erosion-resistant crop rotations. We suggest soil conserving grass-grain crop rotations, including 50–80% perennial grasses (Table 5), for soils in Group III on 5–7^{o} slopes with light soils and on 7-10^{o} slopes with heavy soils. These slopes should be arranged into fields suitable for tillage.

Table 5

The erosion-resistant crop rotations for Group III fields (see Table 3)

<u>I. ≤57% grasses</u> 1. Winter grains, 2. Winter grains, 3. Spring barley, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses, 7. Perennial grasses.	<u>II. ≤57% grasses</u> 1. Winter grains, 2. Spring barley, 3. Spring barley, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses, 7. Perennial grasses.	<u>III. ≤50% grasses</u> 1. Winter grains, 2. Spring barley, 3. Spring barley, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses.
<u>IV. ≤50% grasses</u> 1. Winter grains, 2. Cereal grains with legumes, 3. Spring barley, 4. Perennial grasses, 5. Perennial grasses, 6. Perennial grasses.	<u>V. ≤43% grasses</u> 1. Winter grains, 2. Cereal grains with legumes, 3. Cereal grains, 4. Spring barley, 5. Perennial grasses, 6. Perennial grasses, 7. Perennial grasses.	<u>VI. ≤40% grasses</u> 1. Winter grains, 2. Cereal grains with legumes, 3. Spring barley, 5. Perennial grasses, 6. Perennial grasses.

Group IV includes 2–5^{o} slopes with light soils and 3–7^{o} slopes with heavy soils, and utilizes the soil conserving grain-grass crop rotation, including 33–50% perennial grasses (Table 6). When growing grain crops, it is important to use soil conservation tillage and fertilizers on the undulating topography.

Table 6

The erosion-resistant crop rotations for Group IV fields (see Table 3)

<u>I. ≤38% grasses</u>	<u>II. ≤33% grasses</u>	<u>III. ≤33% grasses</u>
1. Winter grains, 2. Cereal grains with legumes, 3. Spring barley, 4. Winter or spring grains, 5. Spring barley, 6. Perennial grasses, 7. Perennial grasses, *8*. Perennial grasses.	1. Winter grains, 2. Spring grains, 3. Cereal grains with legumes, 4. Spring barley, 5. Perennial grasses, 6. Perennial grasses.	1. Winter grains, 2. Winter grains, 3. Cereal grains with legumes, 4. Spring barley, 5. Perennial grasses, 6. Perennial grasses.

Group V includes the remaining fields with flat to gently undulating relief. Common field crop rotations containing row crops can be used on these soils. However, we suggest using conservation tillage on 2–3^{o} slopes.

Other soil conservation measures. Even grass-grain crop rotations could not completely prevent soil erosion. The annual rates of soil loss from water erosion under grass-grain crop rotation were 7.2–7.4 Mg ha^{-1} on the 10–14^{o} slope, 4.7-4.9 Mg ha^{-1} on the 5–10^{o} slope, and 2.5 Mg ha^{-1} on the 2-5^{o} slope. Soil losses on slopes >10^{o} are greater than soil formation rates, according to local soil profile depth data (Fullen and Catt, 2004; Richter, 1997). Therefore, we recommended grassing slopes >10^{o}, and using conservation tillage and fertilizing-liming 2–10^{o} slopes in conjunction with soil conserving crop rotations.

Deep soil chisel tillage can be used instead of deep mouldboard ploughing, and spraying stubble with Glifosat ($C_3H_8O_5NP$) herbicide can be used instead of stubble cultivation and deep ploughing, which is common in the autumn soil tillage system. Soil erosion rates were reduced 2–9 fold by using these measures, while productivity remained at the same level (Arlauskas and Feiza, 1996). Differentiation of nitrogen fertilizer rates on various parts of hilly-rolling upland (Feiziene, 1996) and matching fertilizer and liming rates to the sensitivity of the crops to soil acidity and erodibility (Jankauskas, 1996) are also important components of this erosion control system.

Activities for recreation and tourism. Excellent conditions exist for the development of recreation and rural tourism on the hilly-rolling landscape, where there are many attractive lakes (mostly on the Baltic Uplands of eastern Lithuania), and picturesque river valleys and lakes (Žemaičiai Uplands of western Lithuania). Cattle breeding for milk and meat, and sheep breeding for meat and wool are the main directions of agricultural activity on the hilly-undulating landscape, where erosion-resisting measures are implemented, and where much inexpensive grass forage can be produced. Breeding of sport horses, bee-keeping (apiary), pond pisciculture, amateur fishing and hunting would be popular and attractive directions for the development of rural tourism.

Towards an integrated policy for agricultural landscapes. Within the Lithuanian agricultural landscape there are many development opportunities. In recent history, the landscape has changed from a predominantly arable system in Soviet times, to a predominantly grassland system and now arable agriculture is increasing, as the agricultural economy focuses on the enlarged market of the European Union (EU). These developments offer opportunities for intelligent land management systems. As discussed, steep and erodible soils could be put to woodland or long-term perennial grassland. To maximize ecological diversity, these areas should be inter-connected, thus providing ecological corridors for the migration of fauna. This will increase biodiversity within the landscape. Less-erodible and gentler slopes could be placed into the identified conservation agricultural systems, carefully designed and targeted on specific segments of the landscape to minimize soil erosion. These are mostly rotational arable systems, with temporary grassland as an integral component of the rotation. This would be a beneficial strategy, carefully maintaining the fund of SOM accumulated through the post-Soviet grassland phase and enhancing the SOM content within the current rotational systems. Such maintenance and enhancement would benefit the soil system (higher SOM/SOC, lower erodibility, improved moisture retention and improved soil biodiversity) and contribute to global objectives of increased C-sequestration and storage.

The proposed vision of the Lithuanian agricultural landscape is fully compatible with specified objectives, such as increasing rural tourism (both national and international). The development of educational farms could be an integral component, explaining the agro-landscape to urban dwellers, particularly children. These trends also fully accord with the development of organic agriculture, which could secure market access within the EU. The integration of all these trends would contribute to a more prosperous and sustainable future for the modern Lithuanian village.

Conclusions

1. The need for soil conserving management systems on the hilly-rolling landscape increases with increased slope gradient and with increased human activities.
2. The soil conserving capability of investigated crop rotations depends on the erosion-resisting capability of constituent crops. Only erosion-preventive grass-grain crop rotations decreased water erosion rates on slopes of 2–14^o by 36.8–80.8% compared with the field crop rotation.
3. Erosion-preventive cropping systems (grass-grain crop rotations and long-term perennial grasses) significantly increased SOM/SOC content when maintained for ≥18 years. Therefore, erosion-preventive crop rotations and other ecosystems assisting erosion control and the ecological stability of the undulating topography, can be considered as major components of a soil protection strategy on undulating landscapes.
4. Sod-forming perennial grasses on 10–14^o slopes and grass-grain crop rotations on 2–10^o slopes enable rehabilitation of degraded land.
5. Erosion-resistant tillage and fertilizing-liming measures intensify the erosion-preventive capability of crops and crop rotations and constitute additional measures of an effective soil protection strategy.
6. Introduction of optimum management systems for soil conservation (sod-forming perennial grasses, soil conserving crop rotations, erosion-resistant soil tillage and fertilizing-liming) assists both soil erosion control and landscape stability on the hilly-rolling landscape.
7. The presented results may have wider applicability on the undulating landscapes of the temperate climate zone, and can assist the development of recreation, rural tourism, educational farms and organic agriculture, thus improving the socio-economic situation and the future vision of the modern Lithuanian village.

References

1. Arlauskas M., Feiza V. (1996). *The problems of hilly agricultural land management and soil tillage* (p. 77–83). Sustainable Agricultural Development and Rehabilitation. Tallinn.
2. Batjes N. H. (1996). *Total carbon and nitrogen in the soils of the world*. European Journal of Soil Science, Vol. 47, p. 151–163.
3. Boardman J., Poesen J. (Eds.) (2006). *Soil Erosion in Europe*. West Sussex.
4. Booth C. A, Fullen M.A. Jankauskas B. et al. (2003). *International calibration of the textural properties of Lithuanian Eutric Albeluvisols.* Agricultural Sciences, No. 4, p. 3–10.
5. Chan K. Y., Heenan D. P., Oates A. (2002). *Soil carbon fractions and relationship to soil quality under different tillage and stubble management.* Soil & Tillage Research, Vol. 63, p. 133–139.
6. Chisci G. (1994). *Perspectives on soil protection measures in Europe*. Conserving Soil Resources: European Perspectives, Wallingford, England, p. 339–353.
7. Ecoscope Applied Ecologists (2003). *Review of Agri-environmental Schemes – Monitoring Information and Research and Development Results.* Final Report for the Department of Environment, Food and Rural Affairs, London.

8. Environment Agency (2001). *Best Farming Practices: Profiting From a Good Environment*. Bristol, England.
9. Feiziene D. (1996). *Differentiation of fertiliser applications on the hills of Western Lithuania.* Sustainable Agricultural Development and Rehabilitation. (p. 133–138). Tallinn.
10. Foster I. D. L., Fullen M. A., Brandsma R. T. et al. (2000). *Drip-screen rainfall simulators for hydro- and pedo-geomorphological research: the Coventry experience.* Earth Surface Processes and Landforms, Vol. 25, p. 691–707.
11. Fullen M. A. (1998). *Effects of grass ley set-aside on runoff, erosion and organic matter levels in sandy soils in east Shropshire, U.K.* Soil & Tillage Research, Vol. 46, p. 41–49.
12. Fullen M. A., Catt J. A. (2004). *Soil Management: Problems and Solutions,* London.
13. Fullen M. A., Arnalds A., Booth C. A. et al. (2006). *Government and agency response to soil erosion risk in Europe.* Soil Erosion in Europe, Wiley Press, p. 805–827.
14. IUSS Working Group WERB (2006). *World Reference Base for Soil Resources 2006.* World Soil Resources Reports No. 103, FAO Rome.
15. Jankauskas B. (1996). *Dirvožemio erozija,* Vilnius, Margi raštai.
16. Jankauskas B. (2003). *Soil Erosion Monitoring Metadata for Modeling of Landscape Change*. EcoSys – Landscape Sciences for Environmental Assessment, Suppl. Bd. 10, p. 88–97.
17. Jankauskas B., Fullen M.A. (2002). *A pedological investigation of soil erosion severity on undulating land in Lithuania.* Canadian Journal of Soil Science, Vol. 82, p. 311–321.
18. Jankauskas B., Jankauskienė G. (2000). *Soil conservation and sustainable land-use programme for the hilly-rolling relief.* Žemės ūkio mokslai, Nr. 3. p. 27–33.
19. Jankauskas B., Jankauskienė G. (2003). *Ecological Land Use in the Undulating Landscape of Lithuania and Baltic Sea Environment*. NATO Science Series. Series V: Science and Technology Policy, Vol. 44, p. 205–213.
20. a Jankauskas B., Jankauskienė G. (2003). *Erosion-preventive crop rotations for landscape ecological stability in upland regions of Lithuania*. Agriculture, Ecosystems & Environment, Vol. 95, p. 129–142.
21. b Jankauskas B., Jankauskienė G. (2003). *Stacionariniai dirvožemio erozijos tyrimai Žemaičių aukštumoje: 2. Vandeninės erozijos intensyvumas*. Žemdirbystė: mokslo darbai, LŽI LŽŪU, Akademija, 82 t. (2), p. 20–34.
22. c Jankauskas B., Jankauskienė G. (2003). *Tillage erosion as a predictor of runoff erosion on cultivated slopes* (p. 589–595). Soil Management for Sustainability, Brisbane, The University of Queensland.
23. Jankauskas B., Jankauskienė G. (2004). *Water erosion rates on the slopes under different land use systems.* Žemės ūkio mokslai, Nr. 3, p. 1–7.
24. Jankauskas B., Jankauskienė G. (2006). *Pasėlių struktūra – dirbamų kalvoto reljefo dirvožemių apsaugos pagrindas.* Žemės ūkis, 2006 balandis, p. 10–11.
25. Jankauskas B., Jankauskiene G., Fullen M. A. (2004). *Erosion-preventive crop rotations and water erosion rates on undulating slopes in Lithuania*. Canadian Journal of Soil Science, Vol. 84 (2), p. 177–186.
26. Jankauskas B., Jankauskienė G., Fullen M. A. (2007). *Relationships between soil organic matter content and soil erosion severity on the Albeluvisols of the Žemaičiai Uplands*. Ekologija, Vol. 53 (1), p. 21–28.
27. Jankauskas B., Jankauskienė G., Fullen M.A. (2008). *Soil erosion and changes in the physical properties of Lithuanian Eutric Albeluvisols under different land use systems*. Acta Agriculturae Scandinavica Section B-Soil and Plant Science, Vol. 58, Iss. 1, p. 66–76.
28. Jankauskas B., Jankauskienė G., Slepetienė A. et al. (2006). *International comparison of analytical methods of determining the soil organic matter content of Lithuanian Eutric Albeluvisols.* Communications in Soil Science and Plant Analysis, Vol. 37 (5 & 6), p. 707–720.
29. Jankauskienė G., Jankauskas B. (2005). *Našų dirvožemį – vaikams ir anūkams.* Mano ūkis, 2005 sausis, p. 14–15.
30. Lal R. (1999). *Soil management and restoration for C sequestration to mitigate the accelerated greenhouse effect*. Progress in Environmental Science, Vol. 1, p. 307–326.
31. Lal R. (2002). *Soil carbon dynamics in cropland and rangeland.* Environmental Pollution, Vol. 116, p. 353–362.
32. Lal R. (2003). *Soil erosion and the global carbon budget.* Environmental International, Vol. 29, p. 437–450.
33. Lal R., Kimble J. M., Follett R. F., Cole C. V. (1998). *The potential of U.S. cropland to sequester carbon and mitigate the greenhouse effect,* Boca Raton: FL, CRC/Lewis Publishers.
34. Lobb D. A., Lindstrom M. J., Schumacher T. E. (2003). Soil erosion processes and their interactions: implications for environmental indicators (p. 25–28). OECD Expert Meeting on Soil Erosion and Soil Biodiversity Indicators. March, Rome, Italy.
35. MAFF (Ministry of Agriculture, Fisheries and Food) (1998). *The Soil Code*. London: MAFF Publications.
36. Morgan R. P. C. (2006). *Soil Erosion and Conservation*, Third edition. Blackwell Publishing.
37. Norgailienė Z., Zableckienė D. (1994). *Įvairaus ankstyvumo šienaujamų ir ganomų žolynų parinkimas eroduotose priemolio kalvose.* Žemės ūkio mokslai, Nr. 3, p. 72–76.
38. Richter G. (1997). *The soil loss tolerance*. Newsletter of the European Society for Soil Conservation, No. 2+3, p. 26–27.
39. Römkens M. J. M., Helming K., Prasad S. N. (2002). *Soil erosion under different rainfall intensities, surface roughness, and soil water regimes.* Catena, Vol. 46/2–3, p. 103–123.
40. Tarakanovas P., Raudonius S. (2003). *Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas ANOVA, STAT, SPLIT-PLOT iš paketo SELKCIJA ir IRRISTAT,* Akademija.
41. Torri D., Poesen J., Borselli L. (1997). *Predictability and uncertainty of the soil erodibility factor using a global dataset.* Catena, Vol. 31, p. 1–22.
42. USDA. (1996). *Chemical analysis organic carbon.* Soil Survey Laboratory Methods Manual, Version 3.0, p. 217–227.
43. USDA. (1995). *Soil organic carbon.* Soil Survey Laboratory Information Manual, Report No. 45 Version 1.0., p. 25–28.
44. Vandermeer J., Noordwijk M., Anderson J., Ong C., Perfecto I. (1998). *Global change and multi-species agroecosystems: concepts and issues.* Agriculture, Ecosystems & Environment, Vol. 67, 1–22.

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Dirvosauginės kalvoto ir banguoto kraštovaizdžio žemėnaudos sistemos su turizmo kryptimi perspektyvos

Santrauka

Šiame straipsnyje pateikiami mokslinių tyrimų duomenys buvo gauti Žemaičių aukštumos (Vakarų Lietuva) kalvotame ir banguotame reljefe, kur vyrauja priesmėlio ir priemolio pasotintieji balkšvažemiai (*Eutric Albeluvisols – ABe*). Vandeninės dirvožemio erozijos tyrimai skirtingo statumo šlaituose naudojant keturias skirtingas žemės naudojimo sistemas buvo pradėti 1982 m. Pagrindiniai tyrimų rezultatai, įvertinantys dirvožemio vandeninės erozijos mastą, dirvožemio savybių pasikeitimą ir auginamų augalų produktyvumą, buvo plačiai paskelbti Lietuvoje ir tarptautiniu mastu. Dirvožemio erozijos mastas skirtingo statumo šlaituose ir dirvožemio organinės medžiagos kiekis skirtingu laipsniu nuardytuose dirvožemiuose yra vertinami kaip kalvoto ir banguoto kraštovaizdžio dirvožemio kokybės indikatoriai, reikalaujantys neatidėliotino gerinimo. Tyrimų rezultatai įgalina modeliuoti konkrečias sąlygas atitinkančias dirvosaugines žemės naudojimo sistemas, leisiančias lokalizuoti ir stabilizuoti labiausiai erozijai jautrių kalvoto kraštovaizdžio teritorijų ardymą ir pagerinti nuardytų dirvožemių ekologines sąlygas. Pasiūlytas erozingų teritorijų grupavimas atsižvelgiant į šlaitų statumą ir dirvožemio granuliometrinę sudėtį bei tokį grupavimą atitinkančios antierozinės priemonės: miškų veisimas labai stačiuose lengvos granuliometrinės sudėties šlaituose, našūs ilgaamžiai žolynai žemės dirbimui per stačių šlaitų masyvuose, dirvožemio ardymą mažinanti pasėlių struktūra (antierozinės sėjomainos) glaudžiai siejama su antierozinėmis žemės dirbimo ir pasėlių mitybos priemonėmis. Tuo sudaromos galimybės laukų ir kraštovaizdžio struktūrų pertvarkymui, įgalinančiam maksimaliai apriboti vandens nuotėkį ir dirvožemio ardymą bei sudaryti sąlygas degraduotų dirvožemių savybių atstatymui bei ekonominei plėtrai.

Rekomenduojama dirvosaugiškoji žemdirbystės sistema įgalina plėtoti pieninę ir mėsinę galvininkystę bei avininkystę, prie ko dera turizmo vystymo kryptis su turistus viliojančiais verslais: sportinių žirgų auginimu, bitininkyste, mėgėjiškąja tvenkinine žuvivaisa ir žvejyba, medžiokle. Kartu iškyla poreikis sparčiau internatizuoti ir kitaip saugiai modernizuoti kaimo aplinką, gerinti kaimo žmonių socialines-ekonomines sąlygas.

Pagrindiniai žodžiai: *pasotintieji balkšvažemiai, kalvotas ir banguotas kraštovaizdis, dirvožemio erozija, dirvožemio apsauga, socioekonominė situacija, ekonominė plėtra*.